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ABSTRACT

This paper presents the results of a study designed to provide an empirical test of a learning theory proposed by McKenzie and Staaf in which the student effort enters as an argument in the learning achievement function. The model states that final achievement in economics is equal to the initial stock of knowledge plus improvement, where improvement is given by the product of effort times the learning rate or aptitude. The data source was the entire population of students enrolled in a principles of economics course in two universities. Pre- and posttests were given to all students, with additional academic and biographical data obtained from university records. Complete data were obtained for 689 students. Two findings are apparent in the results: first, the inclusion of an empirical measure of effort is shown to be a statistically significant variable explaining both learning achievement and improvement. Second, a substitute for the initial stock of knowledge proved not to be a significant variable in explaining learning improvement. Results indicate the necessity of including a measure of effort in further research (and its omission from previous studies calls into question the validity of the results derived therefrom). (Author/JK)

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AN EMPIRICAL VERIFICATION OF THE McKENZIE-STAAF MODEL OF AN ECONOMIC THEORY OF LEARNING

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Introduction

This paper presents the results of a study designed to provide an empirical test of a learning theory model proposed by McKenzie and Staaf [5] in which student effort enters explicitly as an argument in the learning achievement function.

In addition to the primary objective of testing the general validity of their model, we also addressed some of the econometric problems associated with model specification and refinement that have been discussed previously in the "Soper-Becker-Highsmith exchange" [8, 1, 4] and considered further by Becker and Salemi [2]. Parts of the paper, therefore, relate directly to these issues.[1/]

Student Effort

It seems very reasonable to expect student scholastic effort to contribute to learning achievement in economics. However, relatively little work has been done to verify the relationship empirically or to determine the quantitative significance of student effort. Soper and Thornton [7], after presenting a model which they claimed was ".....superior to any previously proposed.....," acknowledge that one of the "loose ends" in their study was ".....the absence of a proxy for what might be called 'student effort.'" In a subsequent study Soper [8] uses a system of equations in what was termed a "second generation" model to derive an instrumental variable which serves as a proxy for the efficiency with which a student employs his stock of human capital in studying economics based on the student's academic ability, maturity and his relative success in "passing" a set of quizzes.

Other studies have been reported which controlled for student time as a measure of effort. Becker and Salemi [2] develop a model which incorporates

student time devoted to the course as an explanatory variable for which estimates were obtained using both OLS and TSLS procedures. Polachek Kniesner and Harwood [6], in an unpublished study, analyze the relationship between learning output and the inputs of study time and other factors using the CES production function to model the learning process. An earlier study by Buckles and McMahon [3] also attempted to measure the effect of student time using a conventional OLS linear model.

In only one of these studies, Polachek, et al. [6], was time found to be significant and in this case the results appear to be inconsistent in that time was significant for the total population but not for either the male or female subsets. We would argue that the efficiency of the use of student time in the learning function, i.e., the marginal product of time, depends on a number of factors including, in particular, the student's aptitude and motivation. Therefore, a valid measure of student effort must somehow explicitly take into account the student's ability to use his time productively (his aptitude) and his willingness to do so (his preferences with respect to the available options). Moreover, scholastic effort should be viewed as a dimension of the more general problem of the optional use of time by the student. The instrumental variable "efficiency" derived by Soper [8] takes into account the student's aptitude, but there is no underlying theory of behavior based on motivation other than the assumption that students will respond favorably to a rewards-incentive system provided by the bonus points received for successful attempts at passing the set of quizzes. Using the production function approach, the Polachek study also derives marginal rates of substitution between study time and other input factors, thus demonstrating empirically the trade-offs that do exist in the production of learning.

A more general approach to the treatment of effort which reflects both aptitude and a theory of rational behavior has been proposed by McKenzie and Staaf [5]. They develop an economic theory of learning based on the rational choice work-leisure model of wage theory in which a student's academic achievement in a particular course is determined by (1) his initial stock of knowledge relative to that course, (2) the allocation of scholastic effort to that course, and (3) his aptitude. Effort devoted to a particular course is seen as resulting from the student's acting in a rational decision-making framework with respect to the allocation of his total available time among competing scholastic activities and between such activities and leisure (all other activities). Effort (time devoted to scholastic activities) is transformed into new knowledge (a higher achievement level) according to some "learning rate" which is determined primarily by the student's aptitude as indicated by some general academic ability measure such as SAT scores. At the margin, a change in the student's expenditure of effort on a particular course (1) represents a conscious decision, the real cost of which in a rational choice framework can be expressed in terms of achievement in some other course(s) foregone, and (2) enters the learning theory model explicitly as a causal variable that contributes directly to the level of academic achievement in the particular course realized. They go on to use their theoretical model to analyze a number of student and faculty decision-making situations using conventional comparative statics methods.

As pointed out above, previous empirical research in economic education has been hampered by the inability to measure and to control for student effort. Therefore, an empirical measure of effort, as conceived by McKenzie and Staaf, that is shown to be a statistically significant variable in

explaining student achievement in economics will be of major importance to the continued advancement of empirical research in economic education.

The McKenzie-Staaf Model

The McKenzie-Staaf student choice model defines the student's utility function as

(1) $U = U(X,L)$

or

(2) $U = U(x_1, x_2, ---, x_j, ---, x_n, L)$

where:

x_j = the level of achievement in the jth scholastic activity (course)

L = leisure (all other nonscholastic activities)

Achievement and leisure are assumed to be normal goods so that:

(3) $Ux_j > 0; U_L > 0$

The student's learning function for the jth course is expressed as:

(4) $x_j = a_j + b_j \cdot e_j$

where:

$a_j (\geq 0)$ = initial endowment or stock of knowledge of the jth activity

e_j = effort devoted to the jth activity

b_j = aptitude or learning rate, i.e., the rate at which effort is transformed into achievement for the jth activity; defined as the student's SAT score

Finally, the following total time constraint is assumed to hold:

(5) $T = \sum_{j=1}^{n} e_j + L$

where:

T = total time period under consideration

$\sum_{j=1}^{n} e_j$ = sum of the efforts devoted to the j courses; j - 1----n

L = time devoted to leisure

The Madison-VCU Study

Our study focuses primarily on the learning function, equation (4), in the McKenzie-Staaf model which states that final achievement in economics is equal to the initial stock of knowledge plus improvement, where improvement is given by the product of effort times the learning rate or aptitude. Given any initial stock of knowledge (zero or otherwise), effort is perceived to be given by the ratio of achievement to aptitude, i.e.,

$$(6) \quad e_j = \frac{x_j - a_j}{b_j}$$

It is not possible to measure effort directly but the variable can be defined in terms of x, a and b as in equation (6). The effort variable, "e_j", as expressed in the McKenzie Staaf model, is the ratio of achievement to aptitude when $a_j = 0$, or improvement to aptitude when $a_j > 0$. Effort, defined either in terms of "achievement" or "improvement," can be measured empirically and its relative importance as a variable explaining student performance in economics can be examined by conventional statistical techniques.

Research Design

We tested the hypothesis that "effort" as formulated by McKenzie and Staaf is a significant factor explaining student achievement using multiple regression analysis in which achievement was made a function of "effort" and a set of other predictive variables that have become more or less standard in economic education research. The data source was the entire population of students enrolled in either the micro or the macro semester of a year course in Principles of Economics at James Madison University and Virginia Commonwealth University during the fall term of 1976. The conventional lecture-textbook format was the method of instruction used in all classes.

Pre and post tests were given to all students using the 33 question Hybrid Tuce. Additional academic and biographical data were obtained from University records. Complete data were obtained for 689 student observations.

Four definitions of student achievement were used as dependent variables in two alternate formulations of the McKenzie-Staaf learning function. One formulation conceives the output of the learning function to be a level of achievement attained at the end of the course while the alternate view conceives the output to be an improvement over some initial state.

The four dependent variables used and their definitions, two for the learning achievement models and two for the learning improvement models, are given below:

Dependent Variable	Definition	Designation
Achievement	1. Post Tuce Score	TUCE
	2. Final Course Grade	GRADE
Improvement	1. Post Tuce minus Pre Tuce	DIFFTU
	2. $\frac{\text{Post Tuce minus Pre Tuce}}{33 - \text{Pre Tuce}}$	GAPTU

Several definitions of student effort and aptitude were tested. These definitions along with those for the other independent variables are listed below:

Independent Variable	Definition	Designation
Effort	$\frac{\text{Post Tuce - Pre Tuce Score}}{\text{Verbal SAT Score}}$	VEFF
	$\frac{\text{Post Tuce - Pre Tuce Score}}{\text{Math SAT Score}}$	MEFF
	$\frac{\text{Post Tuce - Pre Tuce Score}}{\text{Combined Verbal \& Math SAT}}$	CEFF
	$\frac{\text{Final Grade}}{\text{Verbal SAT Score}}$	FGV
	$\frac{\text{Final Grade}}{\text{Math SAT Score}}$	FGM
	$\frac{\text{Final Grade}}{\text{Combined Verbal \& Math SAT}}$	FGC

Independent Variable	Definition	Designation
Aptitude	Verbal SAT Score	VSAT
	Math SAT Score	MSAT
	Combined Verbal & Math SAT	CSAT
Location	University Dummy Variable	LOC
Initial Stock of Knowledge in Economics	Pre Tuce Score	PRE
Biographical Variables		
Sex of student	Dummy Variable: 0=female, 1=male	SEX
Age of student	Age	AGE
Classification of student	1=Freshman, 2=Sophomore, 3=Junior, 4=Senior	YR

The definitions of effort involving final grade (FGV, FGM, FGC) were used only in those equations in which the output, achievement or improvement, was measured by TUCE scores. In similar fashion, the definitions of effort which utilize TUCE scores (VEFF, MEFF, CEFF) were used only in those equations in which final grade was the dependent variable. This restriction on the use of the various definitions of effort avoids a specification bias resulting from the presence of either final grade or Tuce scores as both the dependent variable and as a part of the independent variable for effort. Given this one restriction, all possible combinations of definitions for effort and aptitude were used in each of the following four basic models with each model being tested both with and without the biographical variables (age, sex, year) included. The four models are listed below:

Model 1

Dependent Variables: TUCE, GRADE, DIFFTU, GAPTU

Independent Variables: 1.1 EFFORT, LOC
1.2 EFFORT, LOC, AGE, SEX, YR

Model 2

Dependent Variables: TUCE, GRADE, DIFFTU, GAPTU

Independent Variables: 2.1 EFFORT, LOC, PRE
2.2 EFFORT, LOC, PRE, AGE, SEX, YR

Model 3

Dependent Variables: TUCE, GRADE, DIFFTU, GAPTU

Independent Variables: 3.1 EFFORT, LOC, APTITUDE
3.2 EFFORT, LOC, APTITUDE, AGE, SEX, YR

Model 4

Dependent Variables: TUCE, GRADE, DIFFTU, GAPTU

Independent Variables: 4.1 EFFORT, LOC, PRE, APTITUDE
4.2 EFFORT, LOC, PRE, APTITUDE, AGE, SEX, YR

Model 1 conforms most closely to the original McKenzie-Staaf formulation, which expresses achievement as a function of "effort," and controls only for the different universities, with and without the biographical variables. Models 2 and 3 control in addition for the initial stock of knowledge and for aptitude, respectively. Model 4 is the "most completely" specified model and conforms generally to the empirical models that appear extensively in the economics education literature, but with an "effort" variable included.

All of the equations were originally estimated by OLS methods. However, models 2 and 4 for the DIFFTU and GAPTU definitions of learning improvement are actually recursive since Pre Tuce scores appear as both an independent variable and also as part of the dependent variable. For these equations, therefore, estimates of the initial stock of knowledge were derived by regressing Pre Tuce scores on CSAT, AGE, SEX, and YR. Thus, the reported forms for Models 2 and 4 for the DIFFTU AND GAPTU definitions are:

Model 2'

Dependent Variables: DIFFTU, GAPTU

Independent Variables: 2.1' EFFORT, LOC, $\hat{PRE}$
2.2' EFFORT, LOC, $\hat{PRE}$, AGE, SEX, YR

Model 4'

Dependent Variables: DIFFTU, GAPTU

Independent Variables: 4.1' EFFORT, LOC, $\hat{PRE}$, APTITUDE
4.2' EFFORT, LOC, $\hat{PRE}$, APTITUDE, AGE, SEX, YR

where:

$$\hat{PRE} = f(CSAT, AGE, SEX, YR)$$

This specification conforms to the Soper and Becker-Salemi [8, 2] models of learning which use a system of equations to avoid the specification error resulting from Pre Tuce scores appearing on both sides of the regression equation.[2/]

Thus, to summarize, we used two procedures to avoid the specification bias that would result from the presence in a given equation of a Tuce score (Pre or Post) as both an independent and as a dependent variable. First, with respect to Post Tuce, effort was defined as the ratio of the final grade to the student's aptitude (FGV, FGM, FGC) in those equations where Post Tuce score was included in the dependent variable (TUCE, DIFFTU, GAPTU), and in parallel fashion, effort was defined as the ratio of the change in Tuce scores to aptitude (VEFF, MEFF, CEFF) in those equations where final grade was the measure of achievement to be explained. Secondly, with respect to Pre Tuce, estimates of the initial stock of knowledge ($\hat{PRE}$) rather than the actual Pre Tuce scores were used as a regressor in those improvement equations where Pre Tuce was a part of the definition of the dependent variable (DIFFTU, GAPTU).

We could find no significant variation in the results that could be associated with the alternate definitions of effort or aptitude. Therefore, in addition to avoiding the specification basis, these alternative definitions and models permit us to treat the results of this study with a greater degree of confidence than would be justified in the basis of any one definition or model alone.

The only significant variation that was apparent occurred when estimates of the initial stock of knowledge ($\hat{PRE}$) were substituted for actual Pre Tuce scores in the improvement equations (DIFFTU, GAPTU) in the recursive models 2' and 4' to avoid the specification bias resulting from collinearity between Pre Tuce and the residuals.[3/] However, the paper includes only the results of the regressions in which $\hat{PRE}$ was used as the measure of initial stock of knowledge since these results should be the most reliable on econometric grounds. Also in view of the otherwise general similarity in the results obtained, and for obvious reasons of space, the paper includes only the results obtained from Model 4 as specified above. Also, for the same reasons, the paper includes the results obtained from using only two definitions of effort, FGC and CEFF, and only one definition of aptitude, CSAT.

The Regression Equations. The reported results were generated by estimating four basic equations as specified below. Each basic equation was estimated both with and without a set of biographical variables included, thus making a total of eight equations in all. Equations (1) and (2) measure the output of the learning function in terms of an absolute level of achievement using Post Tuce Score and Final Course Grade, respectively, as dependent variables. The equations are specified as follows:

(1) TUCE = f (FGC, PRE, CSAT, LOC, SEX, AGE, YR)

where:

Tuce	= Post (Hybrid) Tuce Score
FGC (effort)	= $\frac{\text{GRADE}}{\text{CSAT}}$
GRADE	= Final course grade
PRE	= Pre (Hybrid) Tuce Score
CSAT	= Combined math and verbal SAT score
LOC	= University dummy variable
SEX	= Sex of student: 0 = female; 1 = male
AGE	= Age of student in years
YR	= Student classification: 1 = Freshman, 2 = Sophomore, 3 = Junior, 4 = Senior

(2) GRADE = f (CEFF, PRE, CSAT, LOC, SEX, AGE, YR)

where:

CEFF (effort) = $\frac{\text{TUCE-PRE}}{\text{CSAT}}$

and all other variables are as defined in equation (1).

Each of the above equations was estimated both with and without the sex, age, and year variables.

Equations (3) and (4) are "improvement" models. They express the output of the learning function in terms of the increase in the student's economic knowledge using the "absolute improvement" and the "gap-closing" models. The equations are specified as follows:

(3) DIFFTU = f (FGC, $\hat{PRE}$, X_3---X_7)

where:

DIFFTU = TUCE - PRE

FGC (effort) = $\frac{\text{GRADE}}{\text{CSAT}}$

$\hat{PRE}$ = an estimate of the initial stock of knowledge

and X_3---X_7 are the remaining variables as defined in (1)

(4) GAPTU = f (FGC, $\hat{PRE}$, X_3---X_7)

where:

GAPTU = $\frac{\text{TUCE - PRE}}{\text{33 - PRE}}$

FGC (effort) = $\frac{\text{GRADE}}{\text{CSAT}}$

$\hat{PRE}$ = an estimate of the initial stock of knowledge

and X_3---X_7 are the remaining variables as defined in (1)

Results

The results of the regression estimates are presented in Tables 1 and 2 below. The simple correlation matrix is given in Table 3. The results of the Farrar-Glauber test appear in Table 4.

Learning Achievement. The results of four equations in which the output of the learning function is expressed as the level of achievement attained at the end of the course are presented in Table 1. Equations (1a) and (1b) in Table 1 were estimated using Post Tuce score to measure achievement with final course grade being used as the achievement measure in equations (2a) and (2b).

An inspection of Table 1 reveals that "EFFORT," "PRE," and "CSAT" are all significant at the .01 level in all four equations. Previous studies generally have shown that final achievement is significantly related to the student's initial stock of knowledge and his general academic ability. Our results, however, show that student effort is a significant factor as well. Also the fact that student biographical variables generally were not significant may suggest that previous studies which have not controlled for effort may have reached the "wrong" conclusions with respect to the importance of at least some of these variables, and perhaps others also. We would expect student effort to be significant but empirical verification has not been demonstrated in previous studies because of not having a satisfactory measure of effort. The McKenzie-Staaf formulation thus appears to have overcome this obstacle.

A comparison of the "t" ratios between equations (1) and (2) suggests that students may be somewhat more successful in translating their expenditure of effort into higher grades than into higher Tuce scores. Moreover, this is what we would expect <u>if</u> we do, in fact, have a reliable measure of effort, because the student almost certainly has a more accurate notion of what constitutes a grade and how to get it than he has of the "economic knowledge" represented by a Tuce score. The University location variable is significant at the .05 level in both equations using Post Tuce as the dependent variable, but in neither of the equations using final grade as the measure of achievement (which might say more about faculty grading systems than about student achievement). Sex also is significant at the .05 level, and class standing at the .10 level, for final course grade but not for the Post Tuce equations. The negative sign for the significant coefficient of sex in equation (2b) and the

nonsignificance for the same variable in equation (1b) may suggest a sex bias (favoring females) in grading that is avoided by using the "objective" Tuce score as the achievement measure.

Learning Improvement. Table 2 includes the results of four additional equations estimated using the recursive system described above in which two definitions of improvement were used as the dependent variable in the learning function.

Student effort and general academic ability again are significant at the .01 level in all four equations in Table 2 as they were in the achievement models. However, in contrast, the initial stock of knowledge variable ($\hat{PRE}$) is not significant in any of the equations. Here again, we find these results, which differentiate the role of the initial stock of knowledge for achievement and improvement, to be quite plausible. A student's starting point logically should affect his ending point, i.e., the greater the stock of knowledge at the beginning of the course the greater should be his knowledge at the end. Since our learning achievement definition is a measure of the ending stock, one would expect Pre Tuce to be significant in explaining Post Tuce or final grade as indicated in Table 1. But, the increase in the stock of knowledge, as measured by the learning improvement definitions, should be independent of the starting point and thus the nonsignificance of $\hat{PRE}$ is to be expected. Previous studies which have not controlled for effort have consistently shown Pre Tuce to be significant in both achievement and improvement models. Our results suggest that improvement in economic knowledge is a function of student effort, not Pre Tuce.

Summary and Implications

This paper presents the results of an empirical study which includes student effort as a continuous variable in regression equations explaining learning achievement and learning improvement based on a theoretical model proposed by McKenzie and Staaf [5]. The paper also explores some of the implications for model specification and statistical results of alternative procedures for dealing with certain econometric problems inherent in the original formulation.

Two major new findings are apparent in our results. First, the inclusion of an empirical measure of effort as formulated by McKenzie and Staaf is shown to be a statistically significant variable explaining both learning achievement and learning improvement. Second, a proxy for the initial stock of knowledge proved not to be a significant variable in explaining learning improvement when the regression model controlled for student effort. (Pre Tuce was still a significant variable in explaining learning achievement, however.) Also, it is recognized that the "second generation" learning models are recursive rather than simultaneous.

While the low $\bar{R}^2$ values obtained for the learning improvement equations are disappointing, these equations can, nevertheless, be taken as a positive indication that the measures of improvement used possess the desirable property of being independent of the initial stock of knowledge when a variable controlling for student effort is included. However, the low $\bar{R}^2$ values for the equations clearly indicate the need for further research. If, as these results suggest, a proxy for Pre Tuce is not a significant predictor of learning improvement, then we need to identify additional factors that are. The possible implications for our results of the continuing problem of the

existence of multicollinearity represents, perhaps, the most serious qualification that must be recognized. Although the simple correlation coefficients between the independent variables in Table 3 do not indicate a serious problem, the results of the Farrar-Glauber tests in Table 4 do indicate significant collinearity between the three most important factors in the learning process identified to date: the initial stock of knowledge, aptitude, and effort. It is possible, therefore, that the somewhat disappointing results obtained for the improvement equations are linked to this problem.

Finally, we think the weight of the evidence clearly argues for the necessity of including a measure of effort in further research (and its omission from previous studies calls into question the validity of the results derived therefrom). Also we think that our results sufficiently validate the McKenzie-Staaf proxy for effort to justify its use in future empirical research. But we view as unresolved issues the question of model specification, especially for improvement models, and the matter of the role and treatment of the initial stock of knowledge. To the "second generation" it appears that birth still is being given.

Table 1. Regression Results for Learning Achievement Models

Equation	Dependent Variable	Independent Variables[1/]									
		EFFORT	PRE	CSAT	Loc.	SEX	AGE	YR	$\bar{R}^2$	S.E.	F
1a	Post Tuce	156.442***	.327***	.014***	.790**				.26	3.96	61.70
		(5.13)	(7.70)	(10.53)	(2.18)						
1b	Post Tuce	159.413***	.308***	.014***	.843**	.137	.018	.264	.26	3.96	35.27
		(5.19)	(7.17)	(10.63)	(2.49)	(0.43)	(0.32)	(1.12)			
2a	Final Grade	36.728***	.051***	.002***	-.040				.16	.90	32.28
		(6.29)	(5.13)	(7.78)	(0.48)						
2b	Final Grade	37.194***	.055***	.0022***	-.058	-.144**	-.012	.099*	.17	.899	20.92
		(6.40)	(5.48)	(7.96)	(0.68)	(2.01)	(0.90)	(1.86)			
	N = 689										

[1/] t statistics appear in parentheses below their respective regression coefficients in the table

*** significant at the .01 level
** significant at the .05 level
* significant at the .10 level

Table 2. Regression Results for Learning Improvement Models

Equation	Dependent Variable	Independent Variables[1/]									
		EFFORT	PRE	CSAT	Loc.	SEX	AGE	YR	$\bar{R}^2$	S.E.	F
3a	DIFFTU	456.726***	-.444	.011***	.561				.05	4.63	9.08
		(2.78)	(1.59)	(3.95)	(1.30)						
3b	DIFFTU	446.722***	---	.007***	.379	-.665	.443	-.179	.04	4.63	6.21
		(2.70)	---	(4.94)	(0.90)	(1.81)	(0.67)	(0.65)			
4a	GAPTU	24.160***	-.018	.0006***	.034*				.07	.22	13.12
		(3.16)	(1.36)	(4.39)	(1.71)						
4b	GAPTU	23.626***	---	.0004***	.027	-.027	.002	-.006	.07	.22	8.88
		(3.06)	---	(6.22)	(1.36)	(1.60)	(0.59)	(0.46)			
	N = 689										

[1/] t statistics appear in parentheses below their respective regression coefficients in the table

*** significant at the .01 level
** significant at the .05 level
* significant at the .10 level

Table 3. Simple Correlation Coefficients

	FGC	PRE	CSAT	LOC	SEX	AGE	YR	CEFF
FGC	1.000	.127	-.266	.068	.023	.041	-.029	.608
PRE	.127	1.000	.229	.010	.155	.039	.040	-.310
CSAT	-.266	.229	1.000	-.236	-.019	.052	-.046	-.118
LOC	.068	.010	-.236	1.000	-.004	.074	.040	.069
SEX	.023	.155	-.019	-.004	1.000	.018	.231	-.038
AGE	.041	.039	.052	.094	.018	1.000	.292	.044
YR	-.029	.040	-.046	.040	-.231	.292	1.000	-.028
CEFF	.608	.310	-.118	.069	-.038	.044	-.028	1.000

Table 4. Farrar-Glauber F and t Statistics

a: Achievement Models

	FGC	PRE	CSAT	LOC.	SEX	AGE	YR
FGC	15.004	5.495	-8.457	-.392	-.941	1.991	-2.095
PRE		16.823	8.059	1.834	4.946	-.680	2.759
CSAT			29.781	-6.569	-2.333	2.972	-2.890
LOC				8.752	-.654	2.811	-.313
SEX					11.935	2.572	-7.090
AGE						14.436	8.549
YR							21.369

b: Improvement Models

	PRE	CSAT	LOC	SEX	AGE	YR	CEFF
PRE	22.847	6.060	2.150	4.587	.209	1.991	-7.940
CSAT		16.254	-6.711	-2.150	2.546	-2.413	1.046
LOC			9.207	-.628	2.677	-.234	1.544
SEX				11.708	2.493	-7.036	-.052
AGE					14.322	8.457	1.674
YR						20.687	-.993
CEFF							13.526

Footnotes

1/ The focus of that exchange was on the econometric problems introduced by the specification error in "improvement" models in which Pre Tuce scores are included as a part of the dependent variable, e.g., the "gap closing" model, and also enter the regression equation as an independent variable. Thus Pre Tuce, to a degree, is made a function of itself and in the process biases the regression coefficients of the remaining independent variables. This in turn may lead to wrongly inferred significance or nonsignificance for particular variables with obvious consequences for recommendations regarding teaching methods, etc. This potential problem was of no immediate concern to us in testing the validity of "effort" in the McKenzie-Staaf model so long the output of the learning function is conceived in terms of a final level of achievement measured as Post Tuce score or final course grade. However, the McKenzie-Staaf model is not unambiguous with respect to the "proper" concept of the output of the learning function. Therefore, to use the improvement models is not inconsistent with their model as specified. But doing so introduces the econometric problem noted above. The studies cited above [8, 2] suggest that the problem can be avoided by using a recursive system in which estimates of Pre Tuce obtained in an initial equation are used rather than Pre Tuce itself in the final predictive equation. We followed this procedure in estimating the improvement models with effort included as an independent variable. Our results from these estimates continued to yield significant coefficients for the effort variable. However, in contrast to the results reported in the above studies, our Pre Tuce proxy was not significant in the final estimating equations and the resulting $\bar{R}^2$'s were lowered considerably.

2/It should be noted, however, that this formulation is a recursive system and not a truly simultaneous model as the above authors have treated it. In a recursive system estimates of Pre Tuce scores can be derived without regressing Pre Tuce against all of the pre-determined variables in the system. Studies such as those cited above [8, 2] which fail to recognize the model as recursive may not take full advantage of the greater flexibility permitted by this technique in attempts to correct for the continuing problem of multicollinearity.

3/Earlier runs using OLS estimates verified the seriousness of this problem in that unrealisticly high $\bar{R}^2$ values were obtained (.90-.96) and the actual Pre-Tuce variable was highly significant and negative.

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